CLAIMS

What is claimed is:

1. A network of variable speed wind turbine generator systems comprising:

a plurality of generators to generate real power and reactive power, wherein one or more of the generators includes a variable frequency converter excitation system to control real power and reactive power flow, and further wherein the variable frequency converter excitation systems are capable of contributing reactive power independently of the generators; and

a system controller coupled with the plurality of generators to control real and reactive power generated by individual generators in the plurality of generators based on thermal capability and/or voltage limits of the individual generators to cause the plurality of generators to provide commanded real and reactive power.

2. The network of variable speed wind turbine generator systems of claim 1 wherein the system controller further regulates voltage at a point of common coupling.

3. The network of variable speed wind turbine generator systems of claim 2 further comprising a line drop compensator coupled with the system controller to regulate voltage at a location other than a point of common coupling using voltage, current and/or power measurements at the point of common coupling.

4. The network of variable speed wind turbine generator systems of claim 1 further comprising switched power management components coupled with the plurality

of generators and the system controller, wherein the switched power management components are controlled by the system controller.

5. The network of variable speed wind turbine generator systems of claim 4 wherein the switched power management components comprise switched capacitors and/or switched reactors.

6. The network of variable speed wind turbine generator systems of claim 1 wherein the individual generators operate as static VAR regulators under any wind condition.

7. The network of variable speed wind turbine generator systems of claim 1 wherein real and reactive power commands are received by the system controller from a utility grid operator.

8. The network of variable speed wind turbine generator systems of claim 7 wherein the system controller operates as a closed-loop controller that regulates real and reactive power at a point of common coupling.

9. The network of variable speed wind turbine generator systems of claim 7 wherein the system controller operates as a closed-loop controller and the network further comprises a line drop compensator coupled with the system controller to regulate real and

reactive power at a location other than a point of common coupling using voltage, current and/or power measurements at the point of common coupling.

10. The network of variable speed wind turbine generator systems of claim 7 wherein the controller provides a unique reactive power command to each wind turbine generator in a wind farm.

11. The network of variable speed wind turbine generator systems of claim 4 wherein the reactive power command is coordinated with adjustments to the switched power management components.

12. The network of variable speed wind turbine generator systems of claim 11 wherein the reactive power command and the switched power management components are operated to optimize one or more of: increased dynamic range of reactive power production, reduced wind farm losses, improved wind farm voltage profile, and improved power production.

13. The network of variable speed wind turbine generator systems of claim 8 wherein the system controller causes each of the individual generators in the plurality of generators to generate substantially the same reactive power.

14. The network of variable speed wind turbine generator systems of claim 4 wherein commands to the individual wind turbine generators include a reactive power component in the form:

$$Q_0 + \left(dQ/dP \right) \mathrm{P},$$

where Q_0 is a nominal VAR operating point that is provided to all wind turbine generators in a system and

$$\left(dQ/dP \right) \mathrm{P}$$

is a reactive power/real power incremental slope multiplied by wind turbine generator power (P).

15. The network of variable speed wind turbine generator systems of claim 13 wherein the commands to the individual wind turbine generators further comprise a real power modulation signal to emulate a governor droop function.

16. The network of variable speed wind turbine generator systems of claim 13 wherein the commands to the individual wind turbine generators further comprise a real power modulation signal to provide power system damping based on measured and/or calculated frequency.

17. The network of variable speed wind turbine generator systems of claim 13 wherein the commands to the individual wind turbine generators further comprise a real

and/or reactive power modulation signal to adjust network power based on a utility reference command.

18. The network of variable speed wind turbine generator systems of claim 17 wherein the system controller operates as an open-loop controller that regulates real and reactive power at a point of common coupling.

19. The network of variable speed wind turbine generator systems of claim 7 wherein the system controller operates as an open-loop controller and the network further comprises a line drop compensator coupled with the system controller to regulate real and reactive power at a location other than a point of common coupling using voltage, current and/or power measurements at the point of common coupling.

20. A method comprising:

determining power to be provided to a predetermined location;

providing commands to individual wind turbine generators in a multi-turbine system, wherein one or more of the generators includes a variable frequency converter excitation system to control real power and reactive power flow, and further wherein the variable frequency converter excitation systems are capable of contributing reactive power independently of the generators, the commands to control real and reactive power generated by individual generators in the plurality of generators based on thermal capability and/or voltage limits of the individual generators to cause the plurality of generators to provide commanded real and reactive power; and

providing power from the wind turbine generators in response to the commands.

21. The method of claim 20 further comprising providing commands to regulate voltage at a point of common coupling.

22. The method of claim 20 further comprising regulating voltage with a line drop compensator at a location other than a point of common coupling using voltage, current and/or power measurements at the point of common coupling.

23. The method of claim 20 wherein the commands to the individual wind turbine generators further comprise a real and/or reactive power modulation signal to adjust network power based on a utility reference command.

24. The method of claim 20 further comprising controlling switched power management components coupled with the plurality of generators and the system controller.

25. The method of claim 24 wherein the reactive power command and the switched power management components are operated to optimize one or more of: increased dynamic range of reactive power production, reduced wind farm losses, improved wind farm voltage profile, and improved power production.

26. The method of claim 24 wherein the switched power management components comprise switched capacitors and/or switched reactors.

27. The method of claim 20 wherein the individual generators operate as static VAR regulators under any wind condition.

28. The method of claim 20 further comprising receiving real and reactive power commands from a utility grid operator.

29. The method of claim 20 wherein the plurality of generators to generate substantially the same reactive power.

30. The method of claim 20 wherein commands to the individual wind turbine generators include a reactive power component in the form:

$$Q_0 + \left({dQ}/{dP} \right) \mathrm{P},$$

where Q_0 is a nominal VAR operating point that is provided to all wind turbine generators in a system and

$$\left({dQ}/{dP} \right) \mathrm{P}$$

is a reactive power/real power incremental slope multiplied by wind turbine generator power (P).

31. The method of claim 29 further comprising sending a real power modulation signal to the wind turbine generators to emulate a governor droop function.

32. The method of claim 29 further comprising sending a real power modulation signal to the wind turbine generators to provide power system damping based on measured and/or calculated frequency.

33. The method of claim 29 further comprising sending a real and/or reactive power modulation signal to the wind turbine generators to adjust network power based on a utility reference command.

34. An apparatus comprising:

means for determining power to be provided to a predetermined location;

means for providing commands to individual wind turbine generators in a multi-turbine system, wherein one or more of the generators includes a variable frequency converter excitation system to control real power and reactive power flow, and further wherein the variable frequency converter excitation systems are capable of contributing reactive power independently of the generators, the commands to control real and reactive power generated by individual generators in the plurality of generators based on thermal capability and/or voltage limits of the individual generators to cause the plurality of generators to provide commanded real and reactive power; and

means for providing power from the wind turbine generators in response to the commands.

35. The apparatus of claim 34 further comprising means for providing commands to regulate voltage at a point of common coupling.

36. The apparatus of claim 34 further comprising means for controlling switched power management components coupled with the plurality of generators and the system controller.

37. The apparatus of claim 34 further comprising means for receiving real and reactive power commands from a utility grid operator.

38. The apparatus of claim 34 further comprising means for sending a real power modulation signal to the wind turbine generators to emulate a governor droop function.

39. The apparatus of claim 34 further comprising means for sending a real power modulation signal to the wind turbine generators to provide power system damping based on measured and/or calculated frequency.

40. The apparatus of claim 34 further comprising means for sending a power modulation signal to the wind turbine generators to adjust network power based on a utility reference command.